

An Adaptive Long-Term Monitoring Plan for Residual Coal Ash and Associated Selenium and Arsenic in a River Reservoir

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ABSTRACT



The December 2008 Kingston ash release discharged approximately 5.4 million cubic yards of coal ash into the Emory River at approximately river mile (ERM) 2.5. The ash traveled upriver as far as ERM 5.75, with some also being transported downstream into the Clinch and Tennessee Rivers. Ash recovery was executed in three distinct phases. Phase 1 focused on removing ash from the Emory River; Phase 2 dealt with ash in embayments and closure of the failed dredge cell. Phase 3 included comprehensive human health and ecological risk assessments of the estimated 500,000 cy of residual ash left in the Emory and Clinch Rivers after Phase 1 dredging ended. The human health risk assessment found potential exposure to the residual ash presented no unacceptable risks. The potential ecological risks were estimated to be: 1) low for most organisms; 2) at most, moderate, for benthic invertebrates directly exposed to ash, arsenic, and selenium in surface sediment and for birds that consume the benthic invertebrates; and 3) localized and diminished with increasing distance from the release area.

This information was integral to the Engineering Evaluation/Cost Analysis risk management recommendation for a Monitored Natural Recovery (MNR) remedy for the residual ash, rather than additional dredging or capping.

The long-term monitoring (LTM) plan to assess the effectiveness of MNR in protecting the resources at risk uses an adaptive monitoring and management framework. An integral component of this approach is exploring causal effects of changed conditions as data is received, with decision points following those analyses to determine whether the monitoring plan needs to be revised. Any changes identified by these ongoing analyses will be incorporated into the next round of sampling and analysis in order to ensure appropriate amounts and types of data are collected to address study objectives.

Adaptive methodologies provide opportunities for effectively responding to changes in conditions and objective decision points for changes in specific monitoring program components. This poster highlights the strategies employed by TVA in designing a practical LTM plan that meets the needs of the CERCLA Removal Action Objectives and remedy selection, documents restoration of the ecological function and recreational use of the river system to pre-release conditions, and provides additional information for other purposes such as assessing Natural Resources Damages recovery.

ON THE ROAD TO RECOVERY



December 23, 2008



July 16, 2013

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PHASE I & II: RIVER DREDGING, EMBAYMENT EXCAVATION & RESTORATION

Objectives:

- Prevent the coal ash release from negatively impacting public health and the environment.
- Contain and remove coal ash from the Emory River to restore flow and minimize further downstream migration of the ash material.
- Properly manage or dispose of coal ash material recovered during dredging efforts.
- Remove coal ash from the North and Middle Embayments and restore pre-spill bathymetry.
- Ensure proper on-site disposal of all coal ash removed from the North/Middle Embayments.
- Design a perimeter wall to withstand earthquake loads.

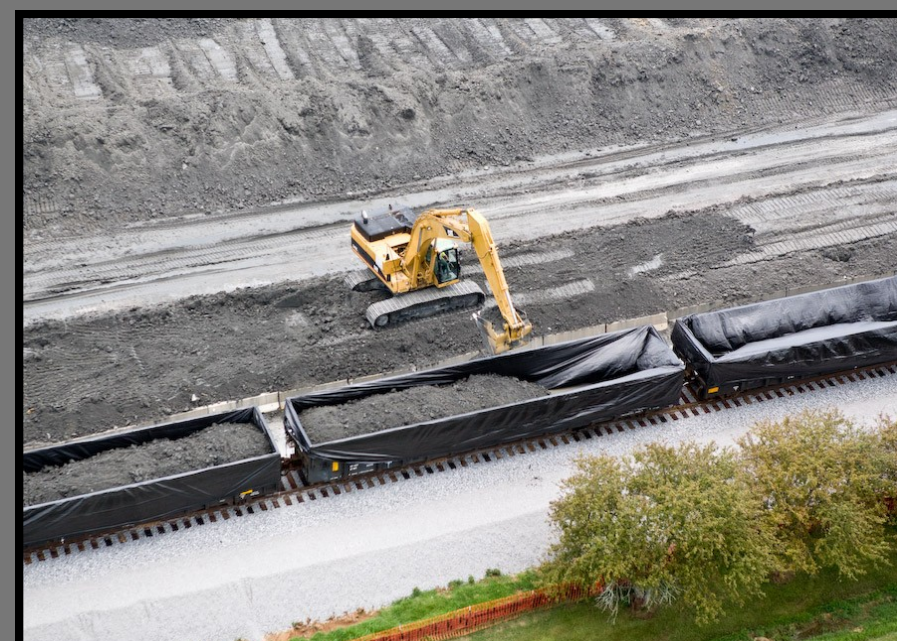
Summary of Actions Completed and In Progress:

- 3.5 million cubic yards of ash removed from Emory River; reopened Emory River to public.
- 4 million tons of ash disposed of at Perry County, AL landfill.
- Removed 2.1 million cubic yards of ash from the North and Middle Embayments.



Ash stacking and consolidation (left); perimeter wall construction (right).

- Consolidated 3 million cubic yards of ash into the re-engineered disposal cell and constructed perimeter wall.
- Dredge cell cap and closure: liner, drainage layer, 2 feet of clay and soil. Anticipated completion date November 2014.



Hydraulic dredge (top); loading ash into railcar for transportation offsite (bottom).

PHASE III: RESIDUAL ASH STUDY

Objectives:

- Characterize nature and extent of remaining ash in the river system.
- Perform comprehensive human health and ecological risk assessments for the river system.
- Evaluate remediation alternatives.
- Develop long-term monitoring program.

HUMAN HEALTH RISK ASSESSMENT

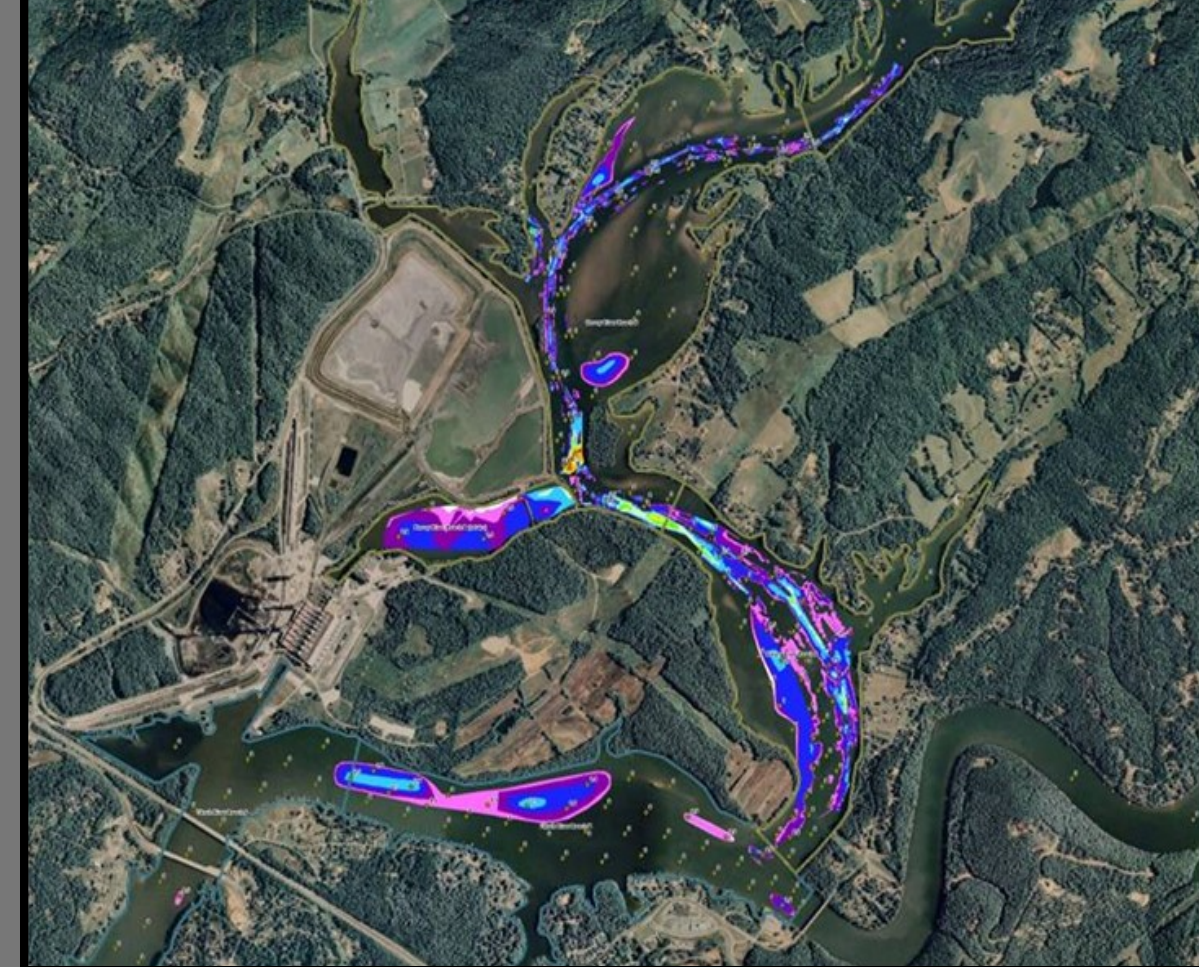
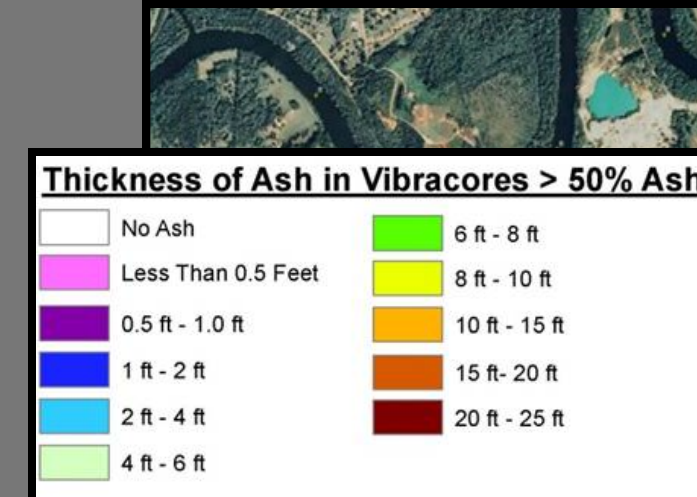
- All detected constituents carried through quantitative calculations.
- Evaluated adult and child residents; adolescent and adult recreational swimmers and beachcombers; and adult recreational fishers.
- Results of the risk characterizations indicated no unacceptable cancer risk or noncancer hazard to any human receptor due to exposure to residual ash.

BASELINE ECOLOGICAL RISK ASSESSMENT

- All detected constituents carried through quantitative calculations.
- Evaluated 14 receptor groups; dietary exposure modeling for 10 birds and mammals.
- Ecological risks from exposure to ash or ash-related COECs are, at most, moderate in the Emory River and low or negligible elsewhere in the river system
- Ecological risks related to residual ash and ash-related COECs are primarily associated with:
 - Direct exposures to ash, arsenic, and selenium in surface sediment
 - Dietary exposures to arsenic and selenium via consumption of invertebrates that inhabit ash-impacted surface sediments

Selected Remedial Alternative: Monitored Natural Recovery (MNR)

NATURE & EXTENT OF RESIDUAL ASH

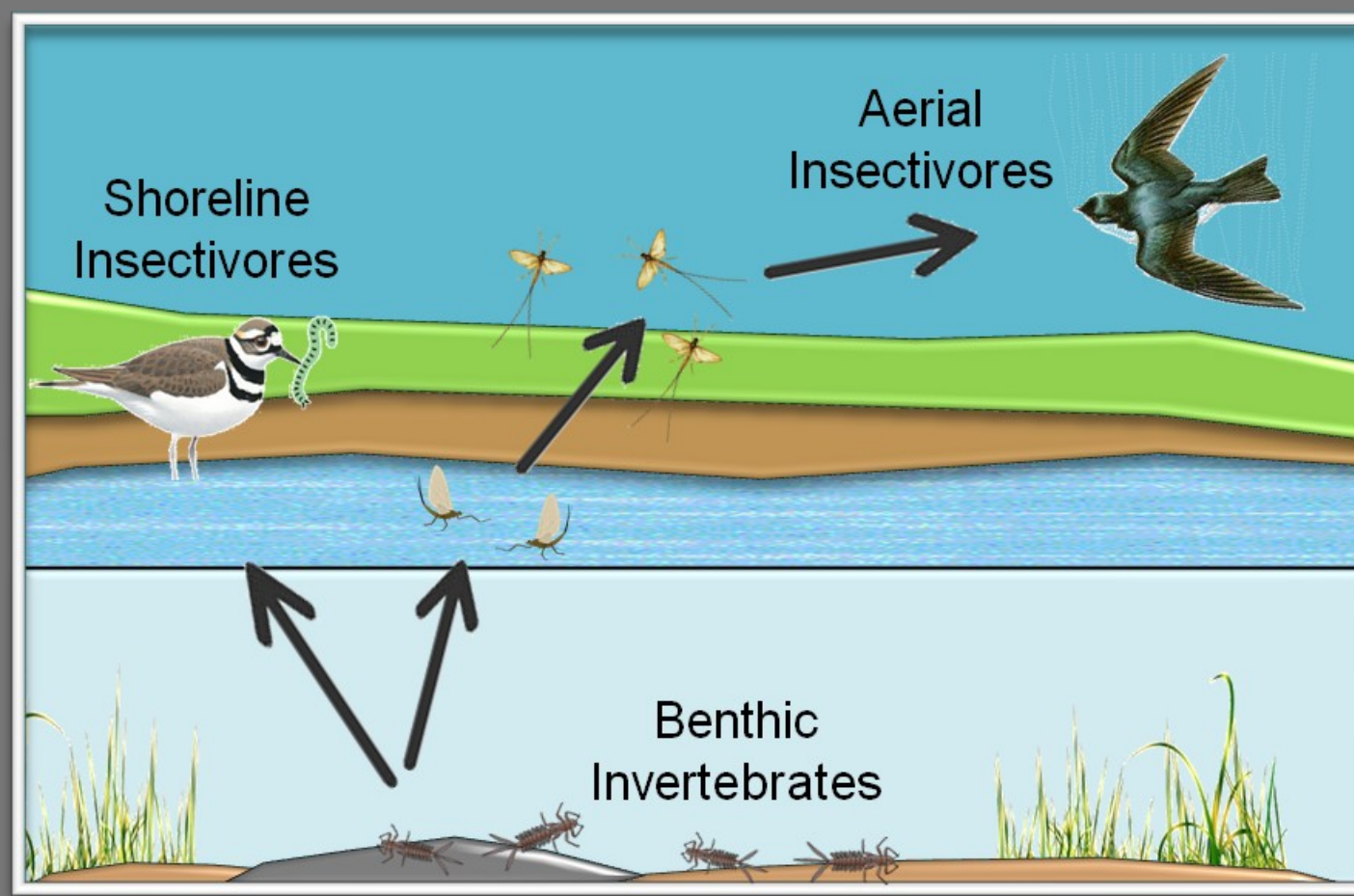


Residual ash in the river system following the completion of Phase I dredging.

LONG-TERM MONITORING PLAN

Removal Action Objectives:

- Protect benthic invertebrate populations from adverse affects due to arsenic and selenium in ash-contaminated sediments.
- Protect aerial-feeding bird (tree swallow) and shoreline or riparian-feeding bird (killdeer) populations from adverse affects due to uptake of arsenic and selenium in ash-contaminated sediment through their diet (benthic invertebrates).
- Restore the ecological function and recreational use of the river system to pre-release conditions.

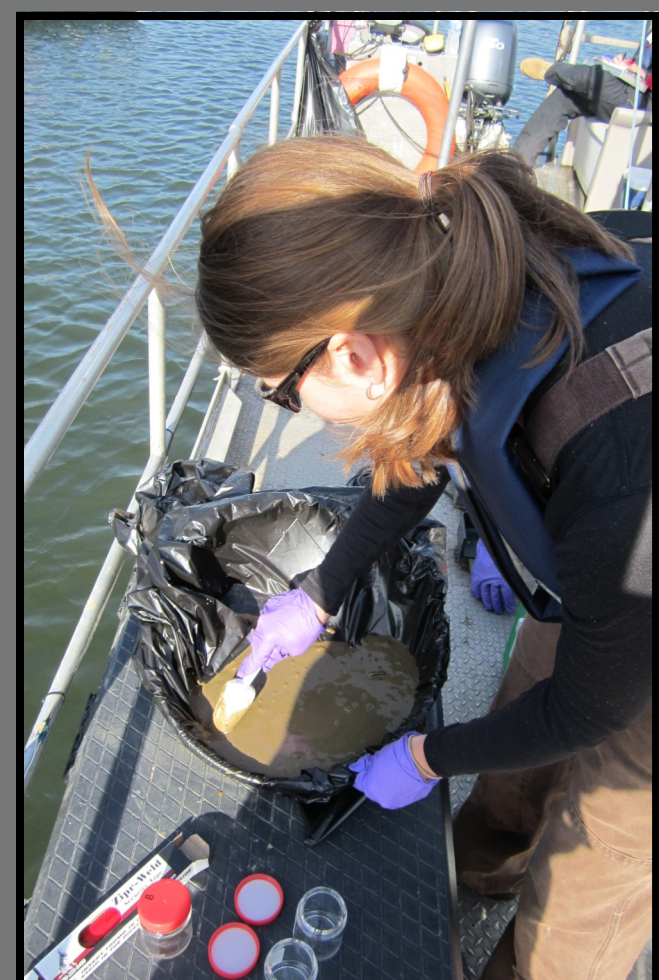


Conceptual exposure model for removal action objectives.

SAMPLING AND ANALYSIS PLAN

Bathymetry & Sediment Transport Modeling, Characterization of Ash, Sediment Monitoring:

- Sediment transport and fate model
 - Conducted by Stephen Scott, U.S. Army Engineering Research and Development Center Waterways Experimental Station (ERDCWES).
 - 2013 update with higher-resolution bathymetry from the Emory and Clinch Rivers
 - Uses 13 grain sizes, representing clay through sand size classes
 - Runs after storm events >110,000 cfs to evaluate mixing and transport or after 5 years
 - After model runs, sediment samples will be collected from several depositional areas to confirm model results or refine model as needed.
- Sediment collected biennially, concurrent with benthic invertebrate community sampling
 - Five locations on the Emory River and four locations on the Clinch River
 - Ponar grabs of upper 6 inches of sediment at each of 10 approximately equally spaced points along a transect
 - Metals analysis for arsenic and selenium
- Sediment toxicity testing in 2013 and 2017.
 - Definitive bioassays using *Hyalella azteca* in 10-day survival and growth tests
 - Two locations on each Emory and Clinch Rivers
 - Uses laboratory-prepared dilution series (0, 20, 40, 60, 80, and 100%) of sediments collected and mixed with corresponding reference sediments
 - Metals, PAHs, pesticides, and percent ash analyses for sediment samples



Co-located sediment (top) and benthic invertebrate community (bottom) sampling.

Benthic Invertebrate Monitoring:

- Community sampling biennially in fall (annual at some locations)
 - 11 transects in Emory and Clinch Rivers
 - Metrics include measures of abundance, diversity, tolerance, and feeding types
- Tissue bioaccumulation biennially in spring/summer (annual at some locations)
 - Collections of mayfly nymph (depurated and non-depurated) and adult samples
 - Collections of snails (depurated and non-depurated)
 - Metals analysis

Aerial-Feeding Insectivore (Tree Swallow) Monitoring:

- Egg bioaccumulation annual in spring/summer
 - Collecting 25 eggs from impacted (ERM 3.0) and reference (TRM 572.5) colonies
 - Metals analysis
- Nest productivity metrics annual in spring/summer
 - Daily monitoring of impacted and reference colonies
 - Clutch size, hatching success, nestling survival to day 15



Male and female tree swallow adults (left); 2-day old tree swallow hatchlings (right).



Fish Monitoring:

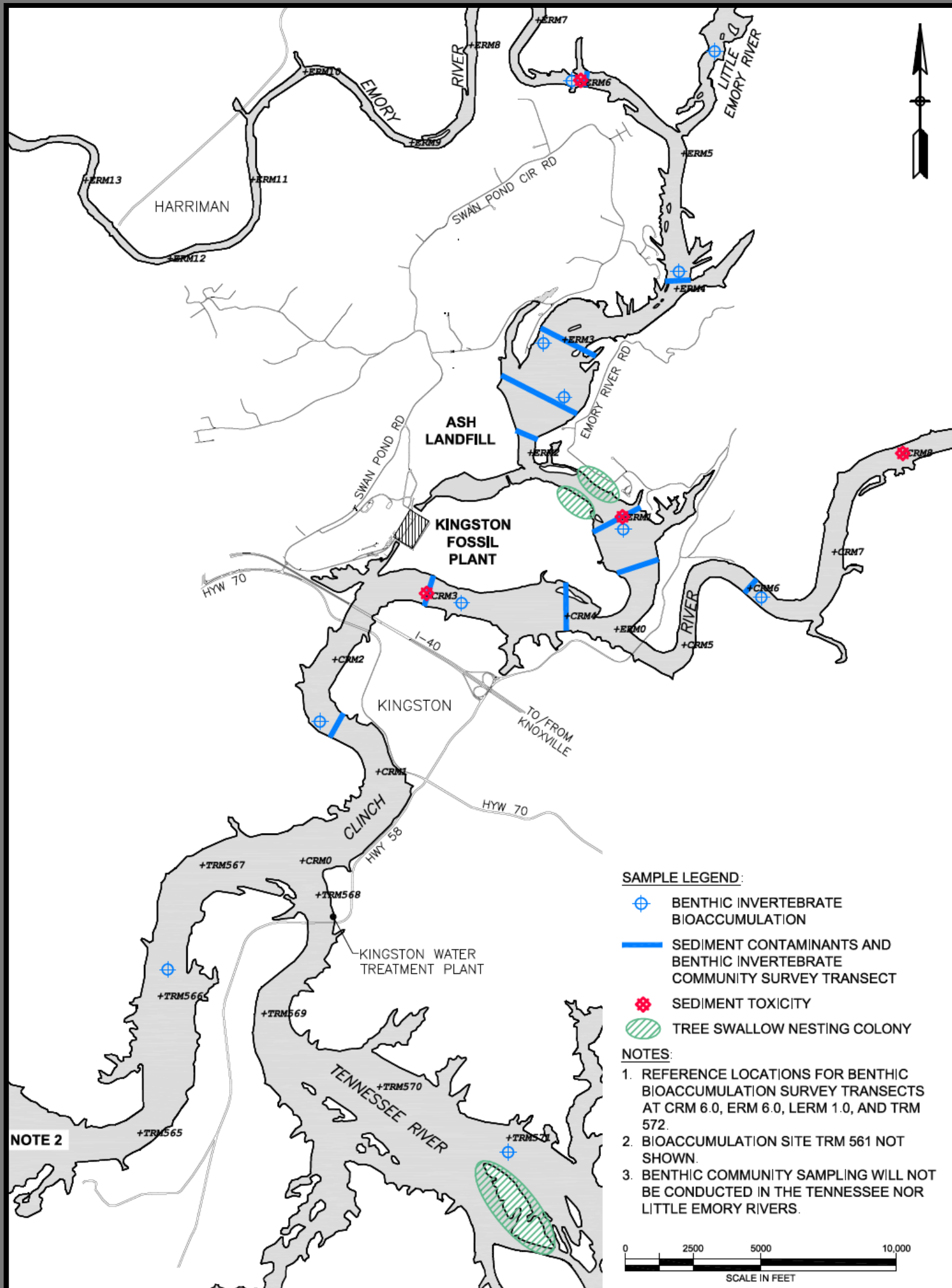
- Tissue bioaccumulation (biennial fillet, liver, and ovary collections from largemouth bass, bluegill and redear sunfish)
- Health metrics and reproduction analyses (concurrent with fish bioaccumulation collections)
- Community (biennial surveys from Emory and Clinch Rivers)
- Spring sport fish survey (biennial surveys of black bass and crappie in Emory and Clinch Rivers)

SUMMARY OF LONG-TERM MONITORING COLLECTIONS

TASKS	LOCATION & FREQUENCY	SAMPLE TYPES
Bathymetry & sediment transport modeling	ERM 5.0 to CRM 2.0 at 200 foot intervals, as needed	Bathymetric contours, stream flows, water surface elevations
Characterization of ash deposits (in support of modeling)	Emory River, only for confirmation of depositional areas after >110,000 cfs storm event	Ash depth, % ash, grain size distribution, As & Se in upper 6" of sediment
Sediment contaminants monitoring	Emory & Clinch Rivers Biennial in Fall (concurrent with benthic invertebrate community sampling)	% ash, grain size distribution, As & Se in upper 6" of sediment
Sediment toxicity	ERM 1.0, ERM 6.0 (ref) CRM 3.0, CRM 8.0 (ref) Fall, 2013	Definitive 10-day Survival & Growth test with <i>Hyalella azteca</i>
Benthic invertebrate community sampling	Emory & Clinch Rivers Biennial in Fall	Population abundance & diversity
Benthic invertebrate bioaccumulation	Emory, Clinch, & Tennessee Rivers Biennial in Spring/Summer	Metals in 3 composite samples of depurated & non-depurated mayfly nymphs, non-depurated mayfly adults, and depurated & non-depurated snails from subset of locations
Aerial-feeding insectivores (Tree swallows)	ERM 1.0, TRM 572.5 (ref) Annual in Spring/Summer	Metals in eggs; nest productivity measures (clutch size, hatching success, 15-day hatchling survival)
Fish Monitoring ** (bioaccumulation, health & reproduction, community, spring sport fish survey)	Emory & Clinch Rivers Biennial in Fall or Spring	Metals in fillet, ovary, liver tissue in largemouth bass, bluegill, & redear sunfish; reproduction condition & fecundity; population abundance & diversity; fisheries information

** The risk assessments conducted for the river system identified no unacceptable risks to humans or biota who consume fish, nor unacceptable risks to the fish community. However, fish sampling was conducted to evaluate recovery of the ecological function and recreational use of the river system for NRDA. Sampling efforts not shown on map.

LONG-TERM MONITORING: SAMPLE LOCATIONS



Sample locations for sediment, benthic invertebrate, and tree swallow collections for the Long-Term Monitoring Plan.

ADAPTIVE MANAGEMENT STRATEGY:

In addition to scheduled periodic reviews, data will be reviewed as it becomes available to identify trends, outliers, or significant changes. Each evaluation will be a decision point for whether there is a need for follow-up studies, or for changes in the monitoring program or the selected remedial action. Outcomes of these reviews could include:

- Continuing the Long-Term Monitoring Plan as previously defined.
- Conducting off-year follow-up monitoring to investigate unusual results.
- Adjusting sampling locations or frequencies (increasing or decreasing, as needed).
- Discontinuing parts of monitoring plan if results suggest decreasing trends over an extended period of time (3+ years).
- Adopting new, more effective monitoring tools.
- Revising Long-Term Monitoring Plan or determining no further action is needed.

